EXHIBIT C

APPLICATION OF REMOTE NITROGEN PLASMAS TO CONTROLLABLY ETCH GATE OXIDE

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I. Introduction

Growing very thin high quality gate oxide (<2.5 nm) is a challenge. Alternative approaches that can be used to achieve the same ends for oxide performance can be attractive. This disclosure will describe an alternative aproach and possible applications where the approach will be advantageous. The approach applies nitrogen plasmas to etch the oxide. The plasmas are generated at a distance from the wafer target. The wafer location is sufficiently far enough from the plasma origin that recombination of the electrons with the ionic nitrogen species occurs. That is, the flux of ionic species reaching the wafer will be reduced from the initial flux created at the plasma's origin. It is in that sense that the term "remote" plasma is used.

II. Invention

We have demonstrated experimentally for nitrogen plasmas generated by the TCP (LAM 9400SE) reactor that combinations of IC power and wafer bias power can be used to controllably etch oxide.

The experimental conditions were that 4.5 nm of oxide was grown, the wafer was masked and quadrants of the wafer were sequentially exposed to different nitrogen plasma conditions. One set involved only variations in bias power with all other parameters fixed:

ICP = 500 W, Pressure = 40 mTorr, Time = 18 seconds,
Bias Power = 15 W, 25 W, 40 W

It was found that a specific amount of oxide was etched for each bias power

setting. As an example, the oxide thickness was reduced to 3.0 nm when the bias power was set at 15 W while the oxide thickness was reduced to 1.7 nm when the bias power was set at 40 W. The uniformity across the wafer was very tight. Ellipsometry measurements were made on the 1.7 nm oxide quadrant and on the masked (unetched) quadrant. Both sets of measurements involved 10 points. The results are collected in Table 1.

Table 1: ELLIPSOMETRY MEASUREMENTS OF OXIDE THICKNESS

Nitrogen Plasma Recipe	Average thickness (nm)	Minimum measured thickness (nm)	Maximum measured thickness (nm)
ICP=500 W, Pressure=40 mTorr, Bias Power=40W, Time=18 seconds	1.689	1.674	1.696
Masked from any plasma (unetched)	4.617	4.603	4.627

It was found that decreasing the ICP value from 500 W to 250 W, while all other factors were kept constant, did not materially change etch behavior. Consequently, for ICP values equal to or greater than 250 W and for pressures sufficiently low that the nitrogen ion flux is not significantly reduced, it is the bias power that will determine the etch rate. However, there will be a bias power level below which the etch rate will be sufficiently low that the plasma can be used for nitridation purposes rather than for etch purposes. However, this is an advantage because the control over the etch rate can be controlled to a degree impossible with any wet etch source. The use of nitrogen also ensures that even if a quantity of that nitrogen were incorporated into the oxide, the incorporation would be beneficial to some degree (such as reducing boron penetration from a polysilicon gate).

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A specific application might be to create multiple gate oxide thicknesses in a region. For example, the oxide is grown to a particular thickness such as 6.5 nm, the wafer is masked and then areas are exposed where it is desired to thin the oxide. These areas are exposed to a nitrogen plasma formed with the recipe given in Table 1. The resulting thin oxide will have a thickness of 3.6 nm. An even thinner oxide could be obtained by extending the exposure time beyond 18 seconds. At the conclusion of the etch phase, the bias power then would be reduced to the level where nitridation occurs in order to form a barrier against dopant penetration from the doped gate. The mask would be stripped and the gate oxides suitably cleaned. This process would avoid the need to use a high dose nitrogen implant into the silicon substrate to both control the oxide growth rate and to serve as the dopant barrier once the oxide was grown. The capability to create multiple gate oxide thicknesses, decoupled either from requiring specific oxide growth rate control or from the nature of barrier formation in the oxide, offers a degree of flexibility that is not possible with current processes if very complex multiple device requirements were necessary for competitive purposes.

In summary, it has been specifically demonstrated for the TCP (LAM 9400SE) reactor that there are combinations of IC power, pressure, and bias power that permit the etch rate of oxide to be controlled by the bias power to a degree that is impossible with any wet etch. In addition, referring to Table 1, the uniformity that is achieved with the nitrogen plasma etch is of the same order as the initial thermal oxidation process.